Chapter 13
Planning Technology Education Facilities

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Planning Technology Education Facilities

1. Introduction

Facilities are a big part of Technology Education. They can certainly contribute to the success or failure of a program. By themselves, however, facilities, either good or bad, are seldom sufficient to make or break a program. Instructors face one of two situations with respect to facilities:

They can find themselves in an existing facility that they will have to live with - although renovation is always possible.

They can find themselves involved in establishing brand new facilities.

Most instructors will find the former to be the case and will be addressed later in this chapter. Consequently this guide will also emphasize this section. However, the principles involved in planning new facilities, provided in this chapter, also apply to the planning of renovations.

2. Background Information

Curriculum Changes Mean Changing Environments

Clearly the future is here! Major curriculum changes are placing new and exciting demands on learning environment design. The implications go beyond remodeling around a few new additions such as computers, mouse trap vehicles, etc. More significantly, it is important that facilities be designed to be "quick on their feet" as technology continues to expand and change. In a very real sense – the future is now! The implications for facility change are real.

Trends in Technology Education Facility Design and Equipment

There is a clear trend toward the establishment of cluster laboratories in Technology Education. Often such facilities are large enough to allow sub-division by partitions (as long as building codes are maintained!) that divide comprehensive laboratories into more specialized facilities. For example, a comprehensive materials and processing laboratory may be sub-divided into unit laboratories for areas such as manufacturing, construction and materials testing. Similarly, an energy & power facility may be divided into fluidic, engine and electronics laboratories, or a communication laboratory may be divided into unit facilities for visual, audio and telecommunications.

Today the best new facilities are provided with modular utility systems that enhance flexibility making rearrangement of the laboratory easier. Also important to flexibility is the use of portable equipment and tool storage. Roll-around cabinets, carefully tailored storage systems, and tables are often used to tailor instruction in varying areas of the facility.

Modular and table-top technology equipment are found much more frequently in today's facilities as are industrial design-based signage systems and bright colors. Multiple activity areas are used to give contemporary facilities a "laboratory" look as contrasted to yesterday's "shop." Of course cleanliness has much to do with this but so does the choice of bench-top and flooring materials. Colorful plastic laminates are prevalent and commercial carpeting is not at all inappropriate for some areas.

More and more simulators, trainers and computers are used to address the challenges of new technology. Generally, instructors are turning to smaller equipment and less multiples of any single items. Instead, a greater variety is purchased in order to help students develop a better appreciation of the tremendous breadth of today's and tomorrow's technology and to assist students in becoming technologically literate.

Types of Space Needed to Deliver Technology Education

One of the important changes affecting TE laboratories in recent years has been an expansion in ***Types of Space*** that is required to deliver the curriculum. Among the space types that should be considered during the facility planning process are:

- Group instructional areas (auditorium, traditional classroom, reconfigurable space)
- Individual instructional areas (e.g., audio-visual workstations, carrels)
- Storage (hazardous materials, student records, project storage, software, supplies, tools)
- Cleanup
- Outdoor
- Specialized/dedicated, e.g.,
  - Recording studio
  - Controlled ventilation
  - Biodome
  - Foundry
  - Display
  - Automated flexible manufacturing or CIM cell
  - Solar or alternative energy area
  - Loading/receiving
  - Instructor's office
  - Library/resource area
  - Computer work stations
  - Video production area
- Research and development space
- Design and prototyping
- Media presentation
- Study space

Technology Education Facilities

When looking at the profession's activity across the nation, it seems clear there is a trend toward cluster courses and standards – based Technology Education. Courses are typically implemented in two distinct kinds of TE laboratories. They are: the comprehensive laboratory and the cluster laboratory.

Comprehensive Laboratories

As the name implies, this type of laboratory is designed to be able to contain a range of activities in one facility. Comprehensive laboratories are used to deliver courses typically using the ***Multiple Activity Approach*** or the ***Design and Technology Approach***. Often such labs designate space for each of the three clusters in Technology Education including Materials and Processing, Energy and Power, and Communication. The laboratory size can vary from small to large. The distinguishing feature is that they are single facilities which have been configured and equipped to deliver learning experiences across the entire range of technological literacy.

Cluster Laboratories

The Cluster type of laboratory is a derivative of the comprehensive laboratory. Its primary feature is that it implements a single technological cluster (i.e., Materials and Processing, Energy and Power, and Communication). Within such laboratories separate space is typically designated for specialized types of equipment or activities, such as a CAD area in a Communication laboratory or a non-destructive materials testing area in the Materials and Processing area.

Modular Laboratories

The Modular type of laboratory provides a system of learning that emphasizes independent study or team learning. This type of laboratory has modular units that generally represent the various technologies found within the National Standards for Technological Literacy. Students rotate through each module at a rate of one to two weeks each.

3. Updating Existing Facilities

How does one best update a TE program? One important dimension is the facility in which the curriculum is taught. Furthermore, facility updating is often the easiest and most effective means of injecting new life and excitement into an older, perhaps even stale, program. Because facility changes are so visible, even relatively small improvements will often have significant effects on students, colleagues and administrators.

Teachers should not imagine that facility updating necessarily demands great investment. To the contrary, often a coat of paint or simple reorganization of existing resources will accomplish much of what is desired. Only after reorganization has reached its limits does renovation need to be considered. Even this, however, is not to be feared for much can be accomplished with relatively minor expense. Examples might include such things as opening a doorway between two adjacent laboratories, adding an outdoor area for construction or alternative energy activities, or establishing a testing room. Schools have a large investment in existing facilities and with some work, most of these can be reworked to provide the type of facility needed to support a quality TE program.

Reorganization

Reorganization of facilities is the easiest and least expensive way to program updating. Often it is what administrators need to see before they are convinced that the teacher is serious about program improvement. Once this becomes clear, increased levels of support typically follow.

In some cases extensive remodeling may not be necessary. Instead, a reorganization of existing space will meet the demands of a new curriculum approach. Many laboratories are not making maximum utilization of available space. Space may be opened up by rearranging machines and equipment. Flexibility may be obtained by providing flexible hose connections to exhaust outlets and connecting flexible pug-in power modules. New color code schemes, removing obsolete equipment and converting large benches into smaller units to form different configurations are a few more ways to improve a facility without great expense.

Renovation

Before beginning facility renovations, instructors are advised to use the Missouri TE Standards (available from the Missouri State Supervisor of TE), to assess their facility's current status. This will provide an excellent base of information upon which to plan the renovation of instructional facilities. To establish the necessary base, it is recommended that TE teachers:

- Use the Missouri TE Standards to assess the existing facility's strengths and weaknesses with respect to the curriculum they have planned.
- Analyze the program's safety requirements.
- Assess the technological relevance of their facility.
- Consider the requirements of the various media they wish to use to deliver instruction.
- Consider team teaching and its facility implications.
- Review the requirements of their instructional and facility management systems.
- Consider the facility's visual impact and public relations effect.

Wisconsin's facility guidelines highlight another most important concern in the planning process, namely the student. "If the student's needs and concerns are not recognized, the basic purpose for which the facility is planned will be defeated. A facility should motivate the student to learn and become aware of what this environment has to offer. It should be a laboratory for learning with action-oriented experiences that enable students to understand the relationship of school work to the world in which they live" (p. 1). Facilities must also be capable of evolving to support the learning activities of technology driven curriculum revisions and expansions.

Instructors need to consider the possibility that the laboratory will have to be multi-purpose in nature—that it will need to be transformed from one type to another. For example, a lab may have to serve students during the day and accommodate community activities during the evening. The Technology Education facility of the future must be one in which change is not only possible but also practical. In order to accomplish this, change must be planned into the facility design.

Instructors must always remember that TE facilities need to be versatile instructional settings and *not* simulated industrial facilities. Consequently, these facilities must be able to respond to whatever setting the curriculum content and/or method demands. The students may be working on individual problems or research, working as a team on a problem, or participating in the process of mass production from product design to product distribution.

Missouri's leaders suggest that if the total estimated cost of modernization is over 30-40 percent of the estimated cost of new facilities then new facilities are cost effective. It is not practical to put money into a structure for which more money will have to be spent again in a few years. A primary question that should be asked is whether the facility, when updated, can house the required educational program. If the answer is "no" then the facility should be replaced. If new facilities are out of the question, old facilities may be updated to serve the objectives of the program. On the other hand, the old facilities may be so outdated that it becomes difficult to implement a program regardless of remodeling.

Numerous physical factors can affect and complicate the process of modernizing existing facilities. These include:

- Inconvenient placement of existing load-bearing walls or supports
- Outdated or inappropriately placed windows or doors
- Changing utility needs (e.g., plumbing, electrical needs for computers, etc)
- The need to isolate "clean" and "dirty" spaces. Some existing laboratories may be directly connected to space that may be incompatible with the requirements of the updated laboratory.
- Temperature and humidity control needs. Many older facilities may require extensive and expensive alteration to accommodate the demands of the new technologies (e.g., air conditioning for laboratories containing computers).

- Shifting enrollment patterns. Increasing enrollments can tax the existing space. A key to the modernization process is to carefully study the projected future space needs.
- Safety codes may require extensive alteration of the existing space during renovation. A major problem has been the difficulties associated with the safe removal and disposal of asbestos.

4. Space Management

One important branch of industrial design is ergonomics. Essentially, this has to do with the important variables that affect the ways in which people interact with their environments. This includes many design factors, such as the proper heights of chairs and work surfaces. Recommendations are also made for the design of instrumentation and control devices (e.g., gauges, control levers, handles, etc.) In the process of designing Technology Education space, it is critical that these important dimensions be researched and considered.

One important aspect of ergonomics is overall space management design and coordination. Essentially, space management is the process of identifying and then managing ***all of the human and physical variables*** that affect the physical facility. Among the important considerations are the following:

- Reviewing and projecting student traffic flow patterns
- Assessing the "per student" space needs for the type of activity which will be conducted in the space
- Time frames within which students will be using the various spaces
- Choosing space configurations that promote "on task" learning (the paired student module approach is a current example of a controlled environment which facilitates student concentration)
- Designing aesthetic factors to promote learning positive attitudes (e.g., lighting, color schemes, seating configurations, etc.)
- Developing a physical environment in which the selected curriculum can be effectively delivered
- Conducting an inventory of all available space in order to identify primary and alternate uses
- Assess the existing space configuration for ways to make it more flexible

5. Planning New Facilities

Overview of the Process

The *curriculum* is the base for facility planning. This must be emphasized because facilities *must* reinforce the goals of the curriculum—this is the key to a successful facility. Beginning here is equally important when planning new facilities or when updating existing facilities.

Often, it is desirable to establish a local Technology Education program planning committee to help design the facility. Candidates for such a committee include: technology education teachers, local supervisors, local administrators, state or university consultants, a representative from industry, a parent, and possibly a student or two. Committee members should be well aware of the local school situation and should be provided with reference materials that will aid in the planning.

Overall, there are three distinct phases in the facility planning process—*Phase One* involves a thorough review of the curriculum, including the overall philosophy and goals for the program. *Phase Two* involves translating the Phase One goals into facility designs and plans. *Phase Three* is when the proposal is transformed into detailed drawings and construction and equipment acquisition. The steps within these phases are:

Phase One

1. Thinking through the program's philosophy
2. Identifying and setting curriculum goals
3. Developing a curriculum plan including an identification of specific courses which will be taught (including future projections)

Phase Two

4. Determining key TE facility design criteria
5. Deriving educational specifications from the curriculum:
    - Space needs
    - Auxiliary spaces
    - Space relationships
6. Interacting with the architect

Phase Three

7. Equipment layouts
8. Construction
9. Acquisition of equipment and materials
10. Installation of equipment
11. Ongoing evaluation and modifications

Developing a Facility Design Portfolio

The preparation of a facility portfolio is extremely important. In order for good planning to achieve results, it is essential that it be packaged into a format which is effectively, clearly, and professionally communicates the facility proposal. Remember, the portfolio is much more than a collection of information. It is also an extremely important *communication piece.* As such, careful attention should be given to make certain that it presents the proposal in the most positive and professional manner possible. The portfolio serves several major functions:

- It is a means of communicating the goals and key ideas to the administration.
- The proposal planning process can be an extremely effective means of helping TE faculty think through their educational goals and philosophy as well as possible new courses, changes in emphasis, etc. Solid facility planning simply *must* be based on a solid foundation of educational planning.
- It is the point of linkage between curriculum clarification and facility design.
- It can serve as an effective tool for educating architects, guidance counselors, school board members, parents and others about TE.

Several suggestions should be kept in mind during the portfolio preparation process:

- Even though the proposal will be first presented to the building administrator, it should be written with other administrators, board members, architects, etc, in mind.
- Don't overwhelm the administration with too much information. A proposal portfolio should be direct, attractive, concise, and accurate. Supporting documentation (such as course and unit outlines) can be replaced in an appendix. It should be able to be easily and quickly read by professional people who are frequently pressed for time.
- The proposal should include a cover letter that serves as an introduction and orientation to the portfolio's content.
- Always have a "second eye" check for grammar and spelling errors.

For suggested components for a facility proposal portfolio, see Figure 13-1

Figure 13-1

Facility Proposal Portfolio Outline

Cover Page:	The proposal should have a professional looking cover page. This is the readers' first impression so it must catch his/her attention. An example might be a creative technology logo or the school logo with an eye catching technology phrase.
Philosophy:	Proposed changes in facilities should be accompanied by proposed changes in educational philosophy. A statement of the new philosophy should be a minimum of a paragraph and no longer than one page.
Goals:	Following the philosophy statement should be a statement of the program goals. It would also be advisable to direct additional goal statements to the cognitive, affective and psychomotor domain.
Courses:	This section should contain the course title, a short description, and the course objectives. Following should be the course units and their objectives, and a description of the activities and the equipment that will be used for each activity. This section should be very detailed so as to show you have done your homework and know how all monies will be spent (See Chapter 3-Scope & Sequence of TE Programs).
Equipment List:	The equipment list should include a detailed description (model #, size, and vendor) for each item, the quantity and item price with a total price.

	Again this shows the detailed preparation and the revision. The equipment needs should be tired back to the goals and objectives.
Floor Plans:	A set of preliminary floor plans should show existing space and new space, utility line runs, and furniture/furnishing placement.
Total Cost Estimate:	This should be an estimate, broken down into categories, of the total cost of the project. It is important to view this as a preliminary estimate. Administrators will want to have some idea of the bottom line costs. While the architect will eventually be responsible for developing detailed cost estimates, preliminary figures can be compiled by some consultation with local contractors, vendors, other schools who have recently undergone renovation, etc.

6. Determining Design Criteria

Space Characteristics

Facility design should be thought of and approached as creating a *total environment* for learning. Viewed this way, facility design goes far beyond the consideration of physical layout. Learning environment design includes a wide range of social, physical and technical factors designed to promote the best interaction possible between teachers, students, and instructional objects. The primary objective of the facility design process should be to *create a learning environment* that can effectively bridge educational goals with student learning. Important design criteria that will promote this process include:

Flexibility of Space	Safety
Utilities	Noise Level & Control
Aesthetics	Environmental Control
Accessibility	Equipment
Control Supervision	Furnishings
Laboratory Security	Lighting

Flexibility of Space

Rapid changes in technology are placing demands on Technology Education facilities. One of the most important of these changes is that changes must be able to accommodate new equipment, different configurations, and new topics as they emerge. The bottom line is that TE facilities of the future are going to have to be designed to be as flexible as possible. Some suggestions regarding how to accomplish this are:

- Use of flexible movement devices, e.g., casters, rollers, or air bearings for equipment, cabinets, etc.
- Non-attached furniture
- Components or modular designs
- Moveable wall panels

- Multipurpose space usage-examples could include:
  - Television studio used as a conference room
  - Darkroom used for light-sensitive plant testing

Utilities

Careful attention and planning should be given to the proper placement of utilities. Important criteria for configuring the systems include safety, flexibility, and appearance. Among the methods which can be considered in the design process include:

- Expansion conduit
- Fiber optic cabling
- Grid system (in ground or power post)
- Bus bar system

The Technology Education facility will need to give attention to the following utilities.

- Phone lines (dedicated for FAX, bulletin boards, etc.
- Computer Network
- Air
- Electricity
- Water
- Drainage
- Exhaust
- Natural Gas
- TV cable

Aesthetics

The modern Technology Education facility is evolving into something quite different from the traditional, unit shop-orientated facility of the past. One of the areas where this change is being felt most directly is in the area of aesthetics. It is very important that modern labs look good. Labs should be designed to make an overall visual impact. This is important for a number of reasons including:

- Attractive facilities send the clear message to parents, administrators and the rest of the school that something exciting and important is happening in your program.
- A sharp and attractive appearance sends a signal to the students that this is a learning environment.
- Attention to aesthetics can engender pride in students, stimulate learning, and provide motivation.
- A good-looking facility promotes an image of excellence and high expectations.
- A high-quality appearance sends the message that the future is now.

Important aesthetic considerations include:

- Color coordination
- Lighting
- Furnishings
- Exhaust
- Display area planning
- Facility materials mix (dry wall, carpet, trim, etc.
- Housekeeping

- Floor, wall, and ceiling coverings
- Plants
- Cornices
- Drop cord placement and concealment
- Signs and poster quality and placement
- Tone
- Texture of the wall, ceiling, floor, and furniture surfaces
- Balance of color, lighting, and overall proportions
- Type of trim
- Painting type and color

Accessibility to the Handicapped

Among the important factors that should be considered when building or renovating facilities, is accessibility for handicapped persons. Sound designs will include attention to factors such as:

- Door widths
- Work counter heights
- Counter depths
- Equipment and work space signage
- Floor covering type
- Clearances around furniture and equipment
- Ramps

Some specifications have been developed by the U.S. Architectural and Transportation Barriers Compliance Board for use by facility planners. These include standards that should be used in the design process. Refer to ADA Standards for Accessible Design (http://www.usdoj.gov/crt/ada/stdspdf.htm).

Control/Supervision

Many new kinds of activities and teaching arrangements are being explored. The individual project and lecture are giving way to more individualized and small group learning. These changes have some important implications for facility design:

- Total visual access to the entire facility should be maintained
- Consideration should be given to a call system (sound or visual)
- Intercom / Announcement capability
- Security must be planned for
- The instructor should have main power switch control
- An amplified public address system should be considered
- Rheostat controlled lighting and specialized spot lighting of certain areas could be desirable
- Intercom systems to help with supervision when students are non-visually accessible

Laboratory Security

Much of the equipment in the modern TE laboratory in not only expensive, it's also compact and could easily be moved. The design of the facility should attempt to maintain a balance between security and availability for the students. The following kinds of concerns should be addressed:

- Arranging for lockable areas
- Lockable power switches
- Alarmed exit doors
- Security cables
- Computer information security
- Security for computer keying
- Tool storage
- Materials storage
- Student project storage
- Lockable storage
- Master keying

Safety

Working with the new technologies often means that teachers may be working with processes and materials that are relatively new to then, e.g. lasers, chemicals, composites, super-chilled gasses (e.g., nitrogen), various experimental combinations, etc. It is therefore very important that the following considerations be followed:

- Carefully read all product information sheets and identification storage requirements
- Consult with other teachers if you are unsure about a process or material
- Contact state department personnel
- Contact safety inspection representatives
- Consult with health officials

Special attention should be given to the following items:

- Railings
- Guards
- Home-made devices (guarding,
- Electrical protection, etc.)
- Special needs and disability concerns
- Egress needs
- Fire regulations (contact the local fire department)
- Fire escape
- Ground Fault Interrupt device protection
- Capacity limitations
- Fire extinguishers
- Communication capability with the office
- Lighting adequacy
- Traffic flow considerations
- Building codes
- Local codes
- Health codes
- National Electrical Code

Noise Level and Control

Even though the equipment in many facilities is moving away from the large and noisy varieties, noise containment remains an important design consideration. Remember, the goal is to develop a positive learning environment. If the acoustics are poor, the overall quality of the environment can suffer. It is important to consider the following:

- Isolation of noisy equipment
- Assess a facility/equipment noise level
- Use of sound absorption materials (ceiling, walls, and floor)
- Control of noise at the source
- Machine mounting pads
- Wear/require hearing protection (e.g., ear plugs)
- Ceiling height

Environmental Control

As with the other design considerations, the environmental control issue is changing for the modern TE facility. Concerns for dust collection and smoke elimination have given way to climate control for computers and other delicate equipment. Important environmental factors that should be addressed include:

- Heating and cooling
- Humidity
- Hazardous vapor elimination
- Dust/Particle control
- Ventilation and air circulation
- Pressurized clean areas

Equipment

Facility design also includes the important component of equipment selection and planning. Among the important variables which should be considered are:

- Scale and size of equipment
- Anticipated future equipment procurement
- Educational or industrial
- Simulation or real
- Table-top or fixed
- Built-in or portable
- Power requirements (e.g., 3 phase)

Furnishings

An important part of any environment is furnishings. Many of the design considerations that hold for facilities in general are also very important for furnishings—for example, flexibility and aesthetics. Furnishings are part of the total learning environment. Poor furnishings can ruin an otherwise beautiful effect. Among the important concerns which should be addressed are:

- Portable or built-in
- Kinds of work surfaces
- Durability
- Safety
- Visual impact
- Flexibility of use
- Expense

Lighting Considerations

The United States National Safety Council has estimated that insufficient lighting was the primary cause of 5% of all industrial accidents and that in 20% poor illumination and eye fatigue played a part. Numerous studies indicate that worker accident and error rates decrease when lighting is improved in industrial settings. Due to its importance, lighting design factors will receive some extended discussion.

Lighting Hints

- Avoid placing light sources in the direct visual field of the operator
- Light sources should be screened (shades, screens, etc.)
- The light source should be a minimum of 30 degrees above horizontal
- In large rooms where the 30 degree minimum is impossible, all illuminants must be screened on the sides
- Avoid designs incorporating polished or highly reflective surfaces on machines, table tops, or other objects in the direct line of sight
- Since desks and benches are frequently located along walls, a distance of 2 ½ feet from the wall to the illuminary should be maintained
- To improve uniformity across a room, it is recommended that somewhat closer spacing exist between outer rows of luminaries than between central rows
- The ends of fluorescent luminary rows should optimally be 6”-12” from the walls and never more than 24”
- Closer spacing is recommended in situations where reduction of harsh shadows is desirable or necessary

Specific Lighting Level Recommendations

Specific recommendations for lighting levels are shown in Figure 13-3. Foot-candles readings can be obtained by using an industrial photometer (or by converting values from a photographic light meter).

Figure 13-3

Specific Lighting Level Recommendations

Area	Foot-candles	Area	Foot-candles
Construction/Manufacturing Processing		Offices	
Assembly Medium assembly……………………..…100 Fine assembly……………………..…..500 Machine Shop Rough bench and machine work……..…50 Medium bench and machine work……100 Fine bench and machine work, grinding, fine buffing, and polishing……………500 Extra fine bench and machine work, grinding, fine work…………………..1000 Finishing Dipping, simple spraying, firing………..50 Fine hand painting and finishing………100 Extra fine hand painting & finishing…..300		Regular office work, reading good reproductions, reading or transcribing handwriting in hard pencil or on poor paper, active filing, index references, mail sorting…………………………………100 Reading high-contrast or well-printed material, tasks and areas not involving critical or prolonged seeing such as conferring, interviewing, inactive files, washrooms…………………………….....30	
Materials Testing		Corridors, elevators, escalators	
Inspection Ordinary……………………………….…50 Difficult………………………………..100 Very difficult…………………………..500 Most difficult…………………………1000		Stairways………………………………..20 Lecture rooms…………………………..70 Toilets and washrooms………………….30	
		Graphic Design & Layout	
		Color inspection and appraisal………...211 Machine composition………………….100 Press operation………………………….70 Proof reading…………………………..150 Drafting rooms………………………...100 Shops…………………………………..150	

7. Educational Specifications

The following section provides a comprehensive listing of the educational specification factors that should be considered when planning facility changes. While each factor will not apply to each program, they should nevertheless be carefully considered, particularly in light of program changes that may be projected for the future. Certainly, one of the primary factors involved in developing educational specifications for modern TE facilities is *FLEXIBILITY*. Every attempt must be made to assure that planning be done with a clear eye on future directions and needs.

Philosophy

The place to begin the process of facility design (and redesign) must *not* be with facility planning. If facility planning is to ultimately be successful, it must be based on a careful review of the program's curriculum. Only *after* the all-important curriculum planning process is completed is facility-planning ready to begin. Therefore, the first question in facility planning in not, "Where do we put the walls?" Rather it should be, "What do we plan to teach?"

The new emphasis on technology has meant a definite shift in TE philosophy and educational goals. The "shop" of the 50's, 60's and 70's falls short of the needs of these new programs. Facilities different from the traditional industrial arts shop are being developed. New Technology Education strategies are focusing on conceptual knowledge of the various techniques (technical skills) with a solid understanding of the technological systems and how they interrelate to each other while interfacing with other disciplines such as mathematics and science.

Trends suggest that we will see more action in the discovery aspects of Technology Education at the elementary level. Students will need to learn to use knowledge to design solutions for problems, and techniques to prototype models that demonstrate the appropriateness of the design solution. Such activity requires facilities that support research, designing, prototyping, testing and storage.

In past years, high school industrial arts programs have been set up as unit shops in drafting, graphic arts, woodworking, metalworking, electricity/electronics, and power. We are seeing a shift from unit areas toward an emphasis on technological systems laboratories. These systems will require modern facilities that contain up-to-date tools and equipment. Lab designs will need to include space for research and experimentation as well as a classroom area for lectures and discussion. Equipment will move from the floor to the desktop in configurations that provide for maximum flexibility. With the introduction of more sensitive electronic equipment for each application, dust, fume and storage considerations will be more critical than ever (adapted from Wright, 1991).

The changes in curriculum which are occurring in Technology Education show a recurring theme; --namely that there is a shift in programs toward a higher-level, design-orientated, technological problem-solving experience as opposed to most industrial arts programs. Collaborative and innovative problem-solving skills cannot easily be learned in a routine and tightly controlled environment. Modern Technology Education facilities should be based upon enabling dynamic technological problem solving in a broad range of technologies (adapted form Doyle, 1991).

Instructional Program

The Department of Design and Environmental Analysis in the New York State College of Human Ecology developed six questions to be answered by an environmental analyst as preparatory to the design of human environments. (Todd, 1974).

- What objectives or goals are these physical and social arrangements created to accomplish?
- Is there a particular philosophy, theory or point of view to be followed in achieving these objectives?
- What behaviors or activities must be carried out?
- Where do these behaviors and activities happen?
- What kinds of procedures, routines or programs have been developed and put into practice to help achieve the objectives?
- When are goal-related behaviors exhibited and in what sequence?
- Summarize the scope and sequence of courses to be offered in the Technology Education program according to grade level.
- List the courses by title and give a brief description of their content.
- Give a short description of the types of teacher and student activities to be implemented in each facility.

Space Needs

Once the instructional program is defined and the scope and sequence of courses established, space needs should be established as a vital part of the educational specifications. Numerous factors must be weighed in determining space:

- Estimate school enrollment
- Estimate of Technology Education enrollment (youth & adult)
- Use class size estimates to calculate the number of class sections necessary
- Determine square footage per laboratory and auxiliary areas
- Consider the type of program being offered including anticipated curriculum changes
- Anticipate the kinds of equipment changes which will be made
- Provide for the needs of special needs populations
- Evaluate traffic flow and station allowances

Each school is different. Therefore, it is necessary to estimate space according to the local conditions. There is a minimum size for laboratories of given types. For specific square footage minimum recommendations, refer to Tables 13-1, 13-2, and 13-3 below.

Table 13-1
SPACE RECOMMENDATIONS GRADES 6-9 [1,2]

Technology Education Course	
General Data (Applies to all laboratories unless listed differently)	Office .... 150 sq. ft. • Processing/work area .... 35% of overall lab area • Class discussion .... 15% of overall lab area • Bench surface .... 15% of overall lab area • Student storage .... 10% of overall lab area • Machine footprint .... 10% of overall lab area • Material storage .... 5% of overall lab area • Supply storage .... 5% of overall lab area • Resource center .... 5% of overall lab area
Introduction to Technology	3240 square feet inclusive 80-135 sq. ft. per student • Materials & Processing area .... 1620 sq. ft. • Communications area (dust free) .... 810 sq. ft. • Energy & Power area .... 810 sq. ft.
Exploration of Technology	3240 square feet inclusive 100-135 sq. ft. per student • Materials & Processing area .... 1620 sq. ft. • Communications area (dust free) .... 810 sq. ft. • Energy & Power area .... 810 sq. ft.
Communication Technology Laboratory	2400 square feet inclusive* 50-100 sq. ft per student overall • Graphic design and production area (CAD, layout, drafting, etc.) .... 1000 sq. ft. • Storage area .... 500 sq. ft. • Darkroom .... 150 sq. ft. • Video control room .... 150 sq. ft. • Stage area .... 150 sq. ft. • Video production/edit area .... 100 sq. ft. • Audio production area (MIDI interface) .... 100 sq. ft. • Audio control room .... 100 sq. ft.
Energy & Power Technology Laboratory	2880 square feet inclusive* 80-120 sq. ft per student overall • Electricity/electronics system area .... 1200 sq. ft. • Transportation systems area .... 1000 sq. ft. • Mechanical systems area .... 600 sq. ft. • Alternative energy area .... 600 sq. ft. • Fluids area (oil, water, etc.) .... 600 sq. ft. • Propulsion area (Rocketry) .... 600 sq. ft. • Storage area .... 400 sq. ft.
Materials & Processing Technology Laboratory • Manufacturing • Construction	2880 square feet inclusive* 80-120 sq. ft per student overall • Construction/manufacturing processing area .... 1000 sq. ft. • Design & production planning area .... 500 sq. ft. • Project and product storage .... 150 sq. ft. • Materials storage area .... 150 sq. ft. • Materials testing area .... 100 sq. ft.

	• Finishing room..150 sq. ft. • Small equipment storage....................................100 sq. ft.
Multi-Purpose Room Classroom Area	....900 sq. ft.
General Data (Applies to all laboratories unless listed differently)	Office ....150 sq. ft. • Processing/work area .... 35% of overall lab area • Class discussion........................... 15% of overall lab area • Bench surface............................... 15% of overall lab area • Student storage............................. 10% of overall lab area • Machine footprint .... 10% of overall lab area • Material storage .... 5% of overall lab area • Supply storage .... 5% of overall lab area • Resource center.............................. 5% of overall lab area
Exploration of Technology (All 3 technologies taught in one facility) General Laboratory	3840 square feet inclusive..........100-160 sq. ft. per student • Materials & Processing area ....1920 sq. ft. • Communications area (dust free).......................960 sq. ft. • Energy & Power area...960 sq. ft.
Multi-activity Facility (2 or more classes simultaneously in facility)	Add the square feet recommendation for each and multiply the total by .75.
Communication Manufacturing Graphics Construction Graphics Engineering Graphics Graphic Communication Electronic Communication	2880 square feet inclusive* 60-120 sq. ft. per student overall • Graphic design and production area (CAD, layout, drafting, etc.) ....1200 sq. ft. • Storage area ....600 sq. ft. • Darkroom..180 sq. ft. • Stage area..180 sq. ft. • Video control room..120 sq. ft. • Audio control room..120 sq. ft. • Audio production area (MIDI interface)...........120 sq. ft. • Video production/edit area ....120 sq. ft.
Energy & Power Energy Systems Electronics Energy and Power Electrical Systems Computer Applications Transportation Systems	3480 square feet inclusive*100-145 sq. ft per student overall • Electricity/electronics system area ....1440 sq. ft. • Transportation systems area ....1200 sq. ft. • Fluids area (oil, water, etc.)……………........720 sq. ft. • Propulsion area (rocketry) ....720 sq. ft. • Alternative energy area.....................................720 sq. ft. • Mechanical systems area ....720 sq. ft. • Storage area ....480 sq. ft.
Materials & Processing Manufacturing	3480 square feet inclusive* 100-145 sq. ft per student overall • Construction/manufacturing processing area ....2400 sq. ft.

Systems Construction Systems Research and Development	• Design & production planning area..................720 sq. ft. • Project and product storage ....720 sq. ft. • Materials storage area......................................360 sq. ft. • Finishing room..180 sq. ft. • Small equipment storage..................................120 sq. ft. • Materials testing area.......................................120 sq. ft.
Multi-Purpose Room Classroom Area	....900 sq. ft.

[1] Existing Facilities: Recommended square feet per student safe area. New facilities should be approx. 20% larger than old facilities.

[2] New Facilities: Recommended design standard should be for a maximum class size of 24 students. All space recommendations contained in this section are based on that recommendation

Table 13-3
Square Footage Minimum Recommendations

SQUARE FOOTAGE OF LAB/TEACHER STATIONS			
School Enrollment	Minimum*	Recommended*	Optimum*
0-500	2400/	3600/2	4800/2
501-1000	3600/2	5400/3	7200/3
1001-1500	5400/3	7200/4	9600/4
1501-2000	7200/4	9000/5	12000/5
2001-2500	9000/5	10800/6	14400/6
2501-3000	10800/6	11600/7	16800/7
*Based upon 20 students per class/lab (does not include planning area but includes storage and finishing areas) Faculty Planning Guide. Technology Education Association of Pennsylvania. Pennsylvania Department of Education.			

Auxiliary Spaces

In order for TE facilities to work effectively, suitable auxiliary spaces are absolutely necessary. These include storage areas for tools, materials and projects, finishing rooms, darkrooms, office space, classrooms and many others as facilities become more specialized.

The following types of auxiliary spaces should be considered and evaluated:

- Tool storage
- Moveable wall sections
- Materials storage
- Hazardous materials disposal
- Storage for portable supply and equipment modules
- Clean-up supplies storage
- Filtered power
- Clean area for specialized activities (e.g., computers)
- Sound isolation space
- Testing area
- Space for maintaining and storing records
- Technical library space
- Research and development area
- Biological research area
- Studio space
- Instructor’s office area
- Finishing room space
- Rest rooms

Space Relationships

The Technology Education department is an integral part of the total school building and should be designed this way. It is normal to position the laboratories on the perimeter of the building because of materials deliveries, the need for large overhead doors and sound control, but they should not be designed as an appendage to the main school building. As an integral part of the educational program, they should be easily accessible to other areas of the school so interdepartmental activities may be implemented.

One particularly useful way of beginning the space organization process is to make a listing of all of the space needs which should be designed into the space. Once this has been completed, assign each space a proportionately sized “bubble.” The size of the bubble should indicate the approximate amount of space which a particular room or activity type is expected to use. Next, combine and arrange individual “bubbles” into the larger spaces in which they will be contained. NOTE: This technique is not designed to designate or design specific spaces, placement of walls, equipment, etc. Rather, it is designed to provide an approximation of space needs and the interrelationship between spaces.

Equipment Layout

One of the most essential features of TE laboratories of the future regarding equipment layout and placement is *flexibility*. Clearly the trend is toward smaller equipment and table-top technology. Additionally, the TE curriculum is demanding new kinds of equipment including lasers, computers, satellite communications, and much more. Much of this equipment is being packaged in modules that provide for easy movement and storage.

It is essential that equipment lists and equipment layouts become a part of the specifications for the architect. It is quite likely that he/she will assume that the equipment needs and layout are much like they have been in traditional Industrial Arts shops. It is very important that they receive thorough orientation to the new layout requirements. Factors which should be considered include:

- Layout for each laboratory, where fixed and moveable equipment will be located
- Give quantity, name, size, floor space (including operator space) and utility requirements for each major piece of equipment
- Give a high priority to future flexibility
- Evaluate safety zones and concerns
- Consider traffic patterns through the laboratory
- Equip larger machines with casters, air bearings, or other movement aids
- Design for flexibility in utilities
- Use strip power
- Arrange lighting to provide for equipment flexibility (in some cases equipment will need to be equipped with specialized lighting)
- Consider the machines which will likely need to be placed close to one another as well as those which may need to be integrated into modules
- Include students in the layout planning process. (This is valuable learning for them as well.)

Construction Factors

During the construction the TE instructor should maintain contact with the architect and contractor concerning the progress of the building or remodeling. Often there emerge electrical, plumbing or other questions that need clarification that only an instructor familiar with the TE program can provide.

8. Interacting with the Architect

Instructors and school system administrators are encouraged to work toward playing an active role in the development of new facility plans. This means that the teacher should be afforded the opportunity to interact with the architect who will design the new facility. This is important because architects are usually not experts in the requirements of the technological curriculum nor are instructors experts in school architecture. What is needed is the systematic blending of the two areas of expertise. This can only come through face-to-face discussion. Mere paper, or even limited oral communications, will not achieve the desired ends.

The architect is one of the valuable human resources who can be tapped through the facility change process. Basically, the architect is in a service profession. His/her primary responsibility is to insure sound, safe, and supervised planning. TE has created some new and very important challenges in working with architects. Simply put, many architects look at our field and our labs and think "*shop.*" Certainly, they are not to be faulted for the misperception. The facility requirements are changing; therefore, careful attention needs to be given to interpreting these new directions to the architect.

Some useful tips to keep in mind when working with architects are:

- Do your homework. Most architects will greatly appreciate information regarding space and equipment needs information, technical specifications, and other preliminary design work. Your sound preliminary thinking will assist the architect in better meeting your goals and needs.
- Always show respect for the architect's knowledge and input; but, be prepared to give your (and your faculty's) input as well.
- Remember, the architect who visits the school usually not the one who draws the plans. Therefore, it is important to remain in touch with the architectural firm and to pass information along on paper. This is particularly important given the changing needs of the TE profession.
- Have a designated person to relate with the architect. It is important to clarify the lines of communication between the architect, administration, and faculty. These will be different for each situation. Clarify and then carefully maintain the proper channels.
- It is important that the administration be kept well informed throughout the building or renovation process. Some architects will take point on this. In other cases, it will be up to a member of the faculty to keep the channels of communication open.
- Early in the project, give the architect a copy of the formal facility change

proposal including the educational goals and curriculum. This will provide valuable information which will help him/her better understand the changing facility needs of TE.

- Provide the architect with photographs or video of some model technology laboratories. This provides a valuable means of communicating the look and requirements of updated facilities. Of course, the best alternative would be to facilitate a tour of selected model programs with the architect (as time permits).
- As the project nears completion, maintain a good listing of the loose ends that need to be completed before the project is signed off. This will make the architect's job go more smoothly and will expedite the time-consuming end-of project detail.

9. Equipping the Program

The TE instructor faces major responsibilities in equipping the TE facility(ies). In doing so he/she must always keep in mind the often conflicting demands of safety, flexibility, relevance to curriculum and costs.

Acquisition and Installation of Equipment

Immediately following approval of expenditures, work must begin on the actual acquisitioning of equipment and materials. This typically is the responsibility of the Technology Education teachers or supervisors who will be working in each of the laboratories. If the equipment list formulated during the development of educational specifications was done well, this step should be relatively easy. The TE instructor should:

- Take the initiative in anticipating and promoting the need for essential equipment
- Maintain an ongoing "punch list" of equipment including an indication of priority and approximate cost
- Become familiar with the school's procurement policy and procedures
- Carefully align projected equipment needs with educational goals and future projected program changes
- Make certain that you are involved in the tool and equipment specification and check-in processes.
- Establish and maintain an inventory and maintenance database for all equipment
- Arrange for appropriate storage of all manuals, supplier information, and warranty information, etc.
- Be certain to inquire into the availability of extended service warranties for particularly fragile or complex equipment
- Arrange for training on specialized equipment—if possible, video-tape the session for later reference
- Consider including students in the training sessions (as appropriate)
- Arrange to have a utility crew present upon the arrival of specialized equipment
- If at all possible, avoid fixed placement of equipment; remember, the future of TE demands *flexibility*

Environmental Considerations

- Specify by laboratory and auxiliary space
- Specify visual, auditory, air, utility, safety, handicapped access/accommodation, ventilation and structural requirements

Evaluation and Modification of Equipment and Facilities

Planning, evaluating and re-organizing should take place continually if a Technology Education laboratory is to remain an up-to-date environment for learning.

- Actively promote input from advisory councils, other colleagues, administrative personnel, industrial representatives, etc.
- Conduct annual facility evaluations and pay particular attention to educational goals and standards.
- Include students in the facility evaluation process

Funding Sources

In the state of Missouri the burden of facility construction and remodeling of elementary and secondary schools lies largely with local school districts. No general programs of federal financial support for school construction have been developed. The following are among the possible sources of funding:

- Pay as you go financing
- The school's internal resources
- Industry partnerships
- Shared facilities with other depts.
- Bond issues
- Funding designated for special needs populations
- Private foundations (e.g., Kellogg, Danforth, Wal-Mart, etc.)
- Leasing of facilities/equipment

10. Maintaining Laboratory Equipment

Even the best facilities and equipment will surely deteriorate quickly if the instructor does not maintain them. Furthermore, a lack of attention to maintenance sends a message to students and the problem quickly grows.

However, the positive side also works. Where it is obvious that the instructor cares about the laboratory, it is easy to instill a similar respect among the students. These points are derived from the experiences of many successful Technology Education teachers:

1. Perform routine maintenance to prevent breakdowns.
   - Establish a preventative maintenance schedule for each machine
   - Enlist student help where it is safe and it contributes to goal achievement

2. Establish a file folder for each machine in the laboratory. This should include:
   - A data card
   - Manufacturer's information

- Parts list and supplier's names (identify parts on hand and their location)
- Maintenance (preventative and special) record

3. Develop systematic facility shut-down/start-up procedures for summer and fall
   - Waxing machined surfaces to prevent rusting
   - Greasing and oiling machines
   - Releasing belt-drive tensions
   - Recharging fire extinguishers
   - Sharpening tools

4. Purchase maintenance contracts on large and complex technological equipment, if it is cost-effective. Otherwise negotiate an agreement with your administration to establish a self-insurance program whereby special maintenance costs do not come out of the TE budget. Point out the liability incurred by school systems when students work on equipment not in proper condition.

5. Establish a portable maintenance toolbox and supply kit that can be quickly picked up and carried to where maintenance is required. This kit should include:
   - A complement of wrenches
   - Punches and chisels
   - Pliers and vise grips
   - Screwdriver set
   - A sample of greases, oils and lubricants and applicators
   - A portable drill and bits, extension cord
   - Hard and soft-faced hammers
   - A volt/amp meter
   - A lock to lock out power and supply switches
   - A set of hang tags to indicate problems/maintenance

6. Use hang tags to indicate machines with problems, e.g.:
   - Do not use
   - Under maintenance
   - Secure instructor permission before operating

7. Incorporate routine maintenance and inspections into the period, daily or weekly clean-up responsibility list.

8. Develop an equipment problem report form and show students how to use it.

9. Annually review the maintenance records to identify growing problems and develop replacement recommendations accordingly.

10. Prepare an annual maintenance report, listing time spent, cost, and activity during the year and submit it to the school administration.

11. Develop a collection of maintenance books and articles.